LA-UR-01-4474

TITLE: ADVANCED ACCELERATOR APPLICATIONS (AAA) SPOKE-CAVITY ED&D POWER COUPLER DESIGN REVIEW

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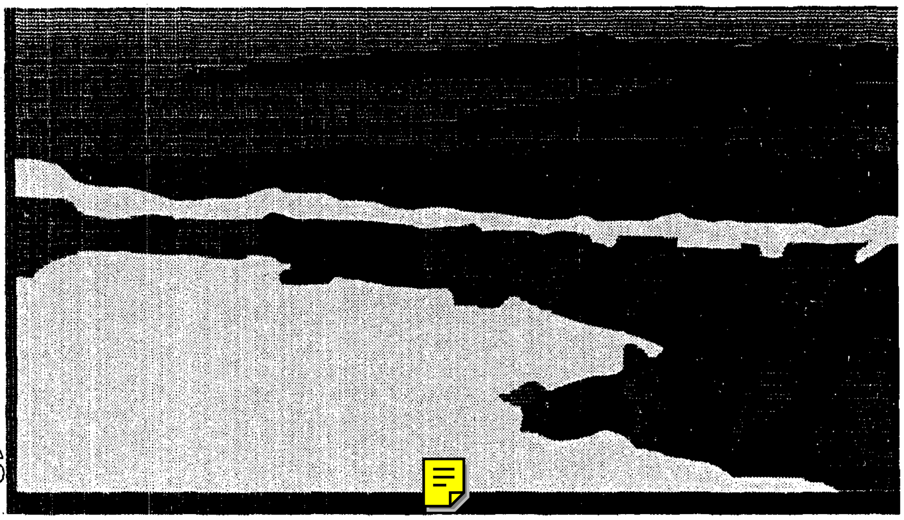
SUBMITTED TO: Informal Distribution - Internal and External



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The attached viewgraphs are from a presentation given to an internal/external review panel for the AAA Project Spoke Cavity ED&D Power Coupler Design Review on August 2, 2001 at LANL. The presentation gave an overview of the AAA/ADTF Superconducting Design work that has been completed to date. This included a description of the design presented at the AAA/ADTF Preconceptual Design Review in April, 2001 and a discussion of the design philosophy. Simulation results for this design were also presented. Finally, recently proposed design changes that impact the power coupler requirements were discussed.

Advanced Accelerator Applications (AAA)

Spoke-Cavity ED&D Power Coupler Design Review

August 2, 2001

ADTF Design Overview

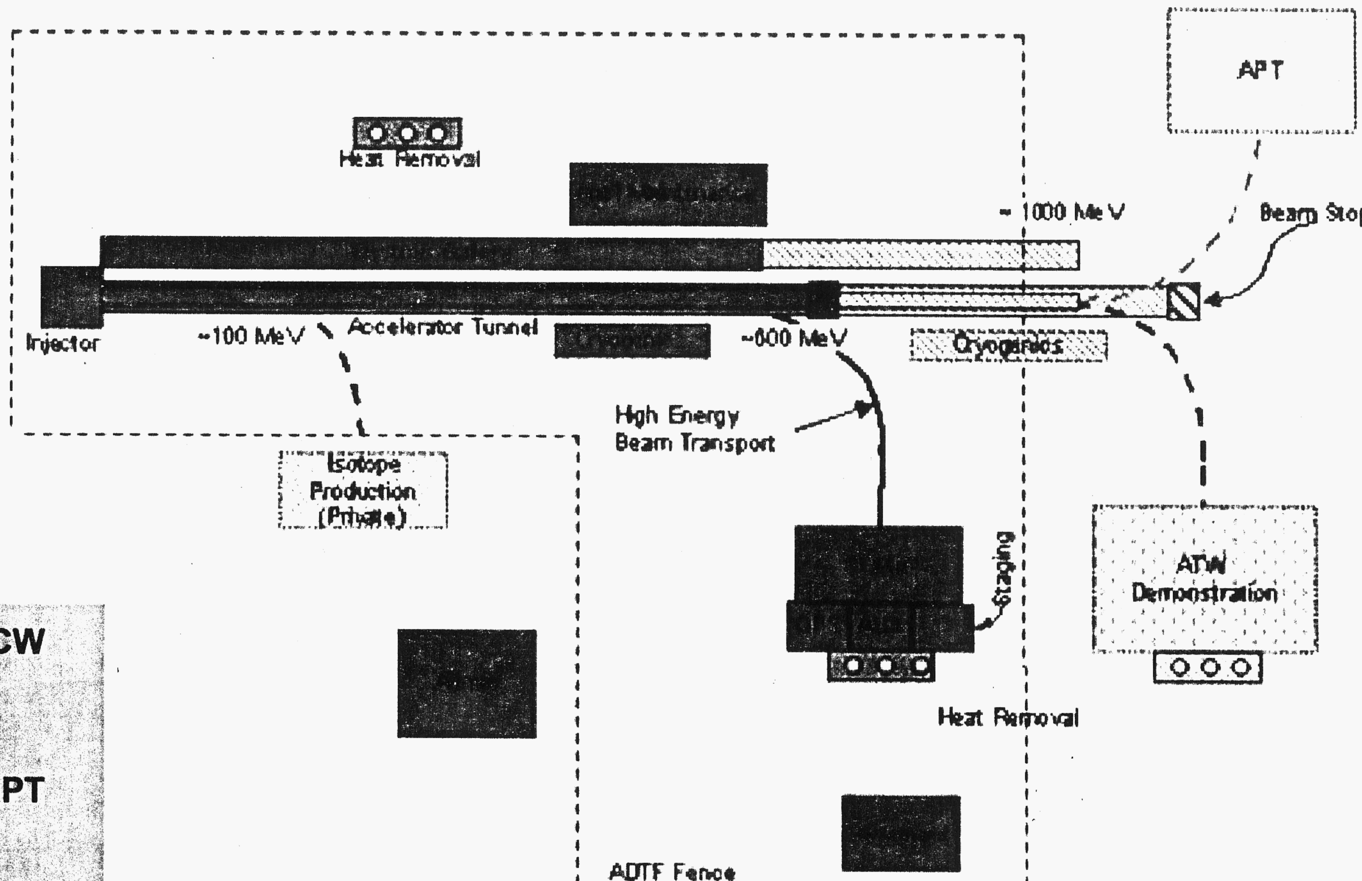
Robert Garnett

Outline

- What is the ADTF?
- Design Description & Philosophy
- Simulation Results
- Recent Proposed Design Changes

  Coupler Power Requirements

What is the ADTF?



Accelerator-Driven Test Facility Concept

- 600 MeV, 13.3 mA CW
- Test bed for ATW, Advanced Nuclear Technologies, and APT
- Subcritical Target/Multiplier Assembly
- Upgradeable to 100 mA, 1GeV for APT, ATW

Why consider a SC low-energy linac?

- Design goal for ADTF - Substantially reduce beam interrupts to limit thermal stresses in the target.
- A SC linac provides advantages for reducing beam interrupts:

-Superconducting technology favors cavities with just a few cells. Combining small number of cells (*large velocity acceptance*) with independent phasing of the cavities produces ability to continue operating even with some RF module failures.

-Larger bore radius *allows off-energy or poorly focused beams after faults to be transported* to the target with minimal beam loss.

-*Provides some inherent tolerance against the most common faults.* Can continue running with failed RF modules, RF cavities, RF windows, magnets, and magnet power supplies.

-*More stable operating temperatures* means beam trips from thermally induced perturbations to cavity RF frequency should be greatly reduced.

Selection of Design Parameters

- APT linac design was our starting point.
- LEDA RFQ output beam characteristics assumed.
- Spoke cavity cryomodule mechanical layout specified by engineering - iterative process.
- Design Goals:

  Avoid Beam Envelope Instabilities

  Achieve Good Beam Capture

  Current-Insensitive Focusing Lattice

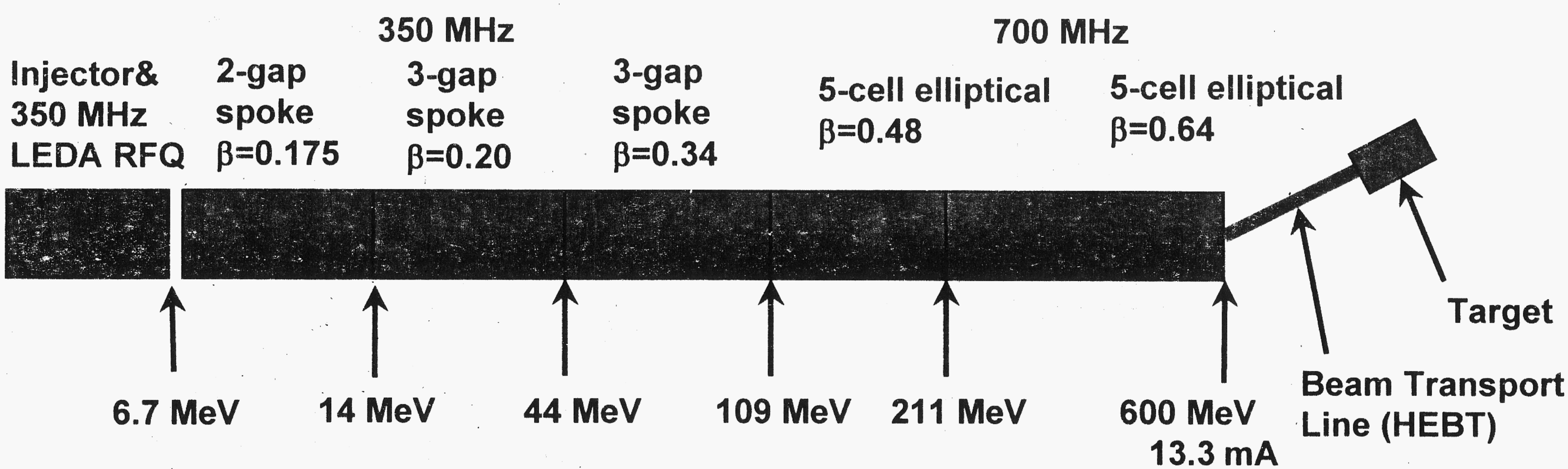
  Efficient Acceleration

  Reduce Beam Interrupts - design inherent insensitivity

  ⇒ Selection of accelerating gradients, synchronous phases, and beam focusing

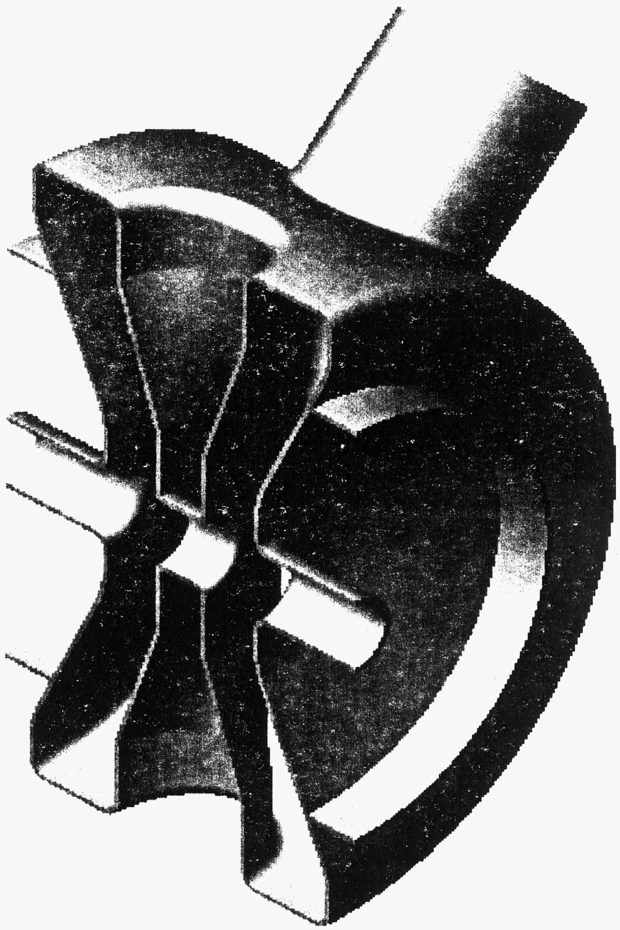
- Parameters are probably not yet optimized.

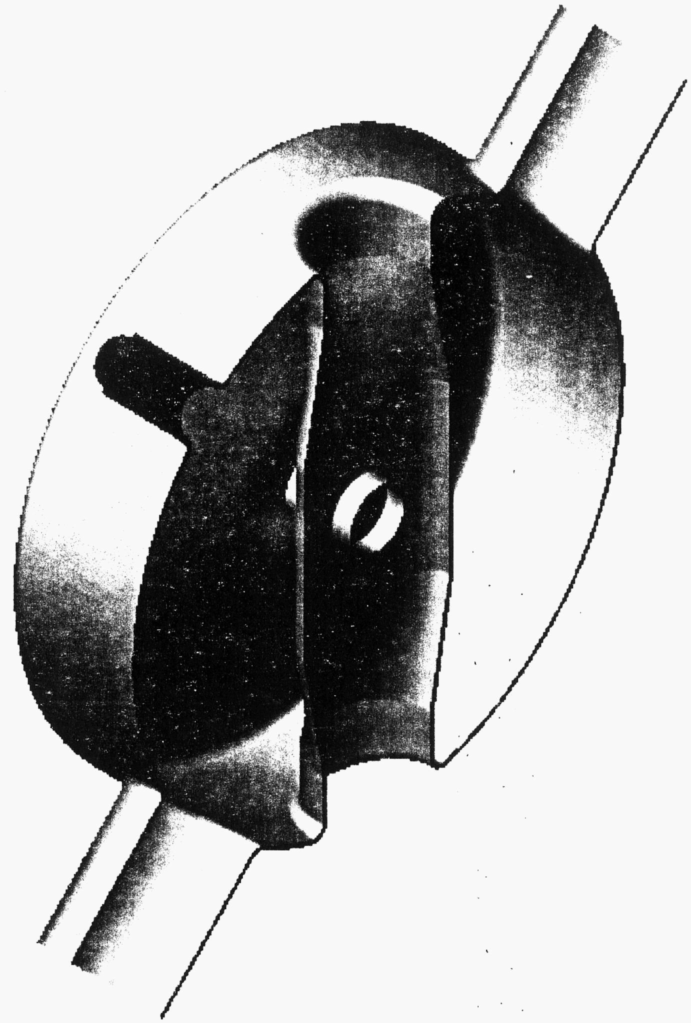
ADTF Superconducting Linac Design (April ADTF Review)



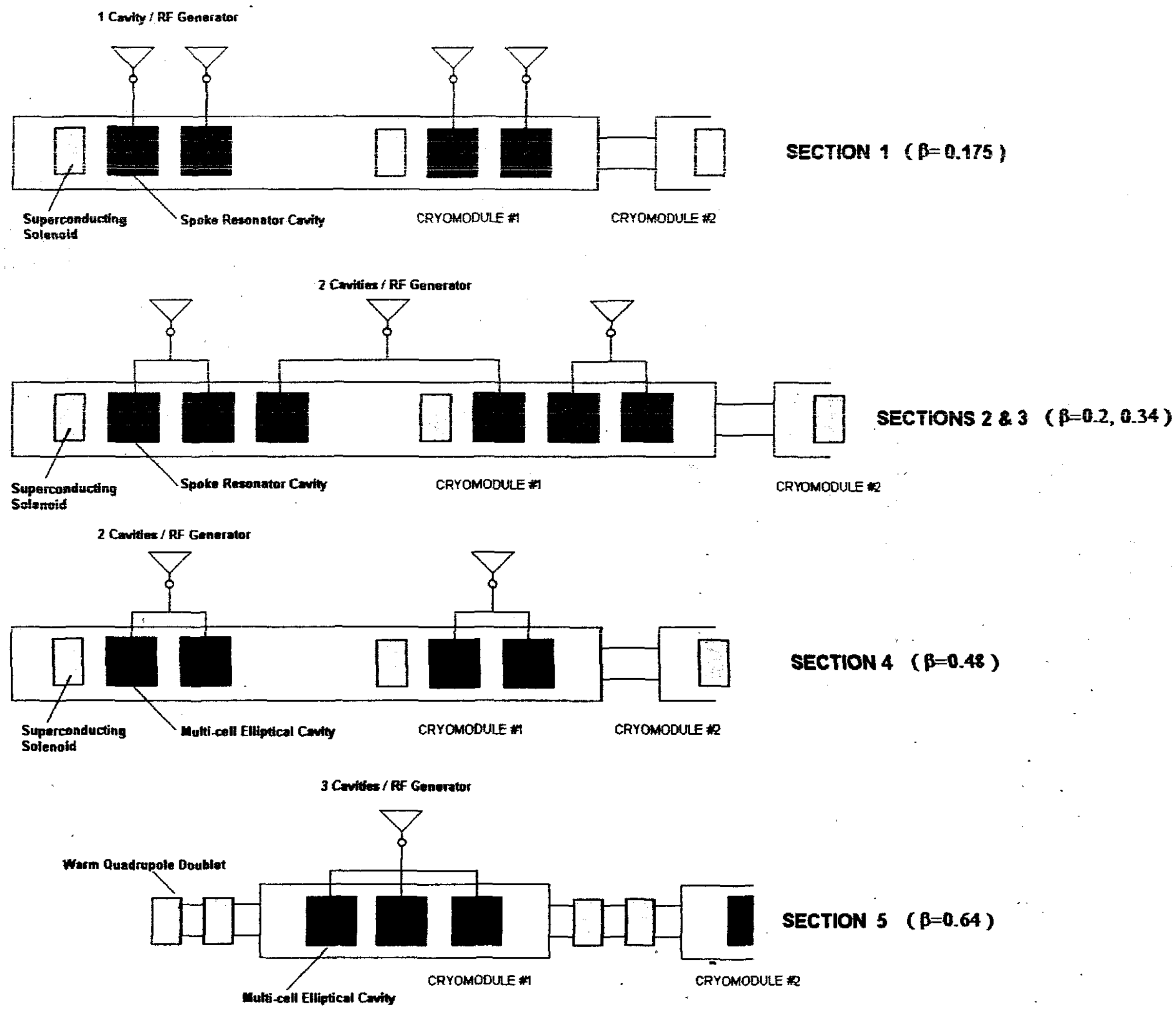
- NC linac to 211 MeV replaced with four new SC sections each with identical cavity shapes and cryomodules.
- Conservative input power-coupler capacity < 60 kW and accelerating gradients (<10 MV/m).
- 131 rf generators, 261 superconducting cavities, and 65 cryomodules. (fewer components than CEBAF).
- Superconducting solenoid magnets for focusing below 211 MeV.
- About 400-m linac length (about 1/2 of LANSCE linac length).
- New SC low-energy linac saves 55 MW AC power.

LANL $\beta = 0.175$ 2-Gap Spoke Resonator

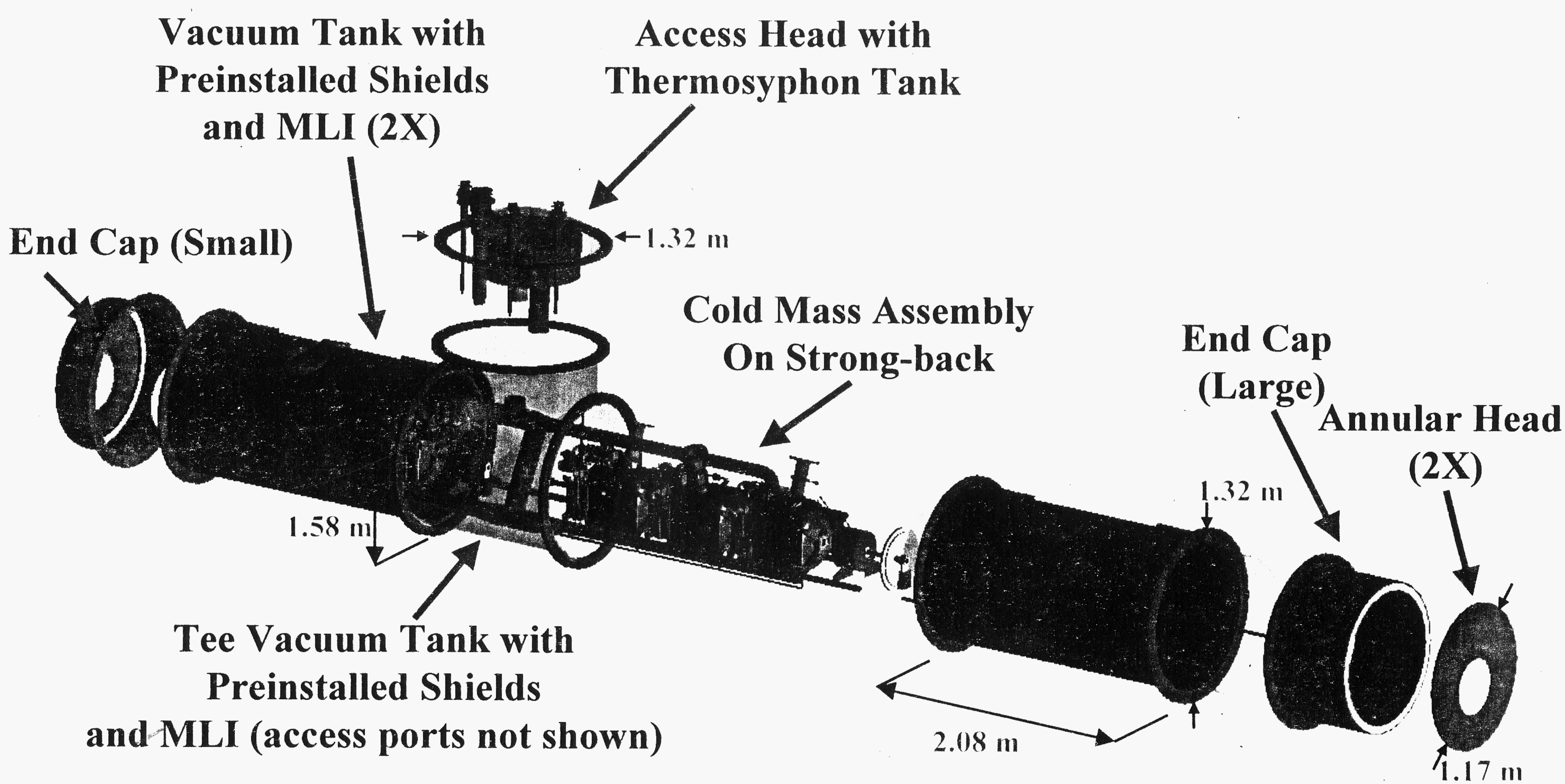




Cryomodule and RF Architectures



6-Cavity Spoke Cryomodule Final Assembly



SC solenoids save power and provide strong focusing with fewer magnets than with quadrupole systems.

- SC solenoids can be installed in the cryostats to provide a periodic focusing lattice.

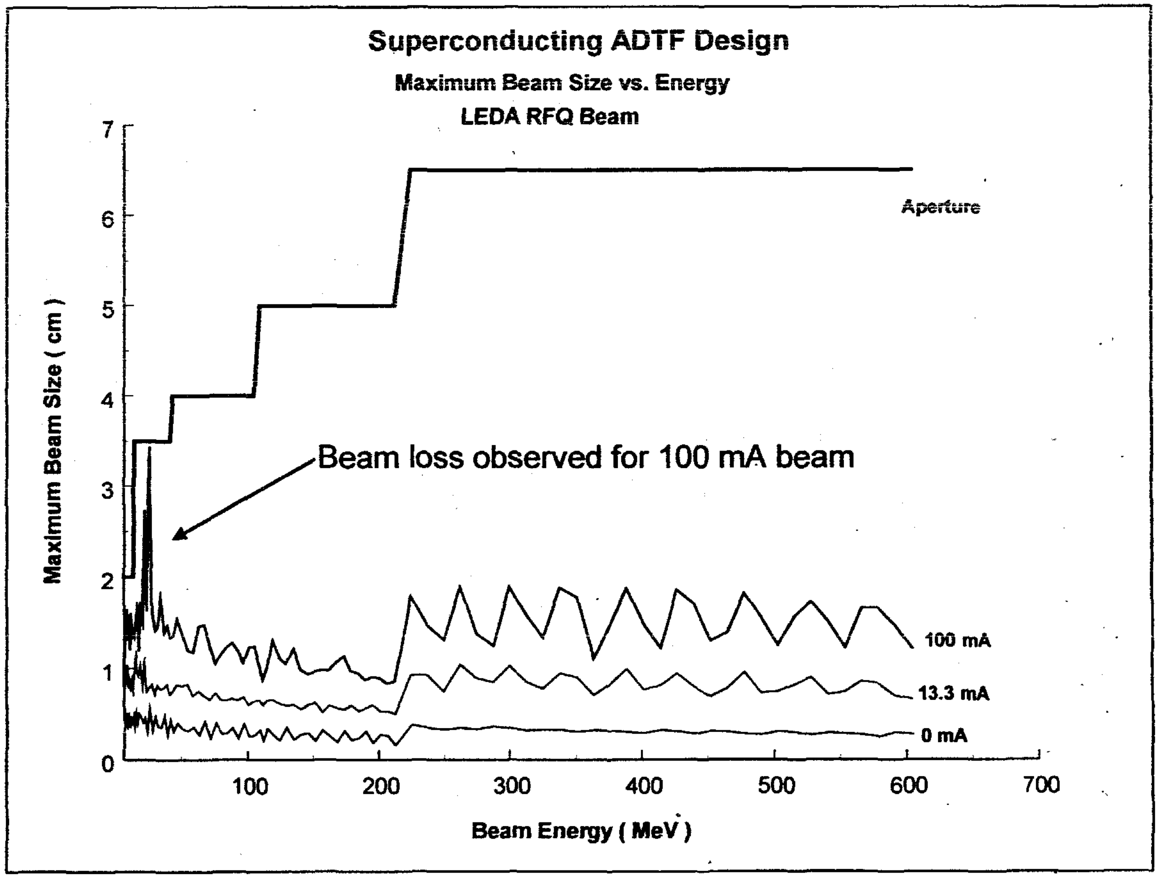
  Persistence-mode operation allows power supply repair during linac operation.

- Solenoids can provide a shorter focusing period resulting in stronger net focusing at low beam velocities. SC solenoids produce higher fields.

- The superconducting design reduces the number of focusing magnets by a factor of 3.

Beam Simulation Results

Ideal Linac, 10,000 Macroparticle LEDA RFQ Distribution



Simulation - Fault / Failure Study Results

- **Single-magnet failures in ideal linac appear tolerable.**

  Study needs to be repeated for non-ideal linac.

- **Multiple sequential magnet failures (>1) result in large beam loss.**

  Loss of both magnets in a cryomodule will cause machine downtime.

- **Uncompensated single-cavity or RF module failures anywhere in the linac result in high beam loss.**

  Compensation for loss of a cavity or loss of an RF module is required and possible.

  Example - Shift downstream cavity operating phases and increase amplitudes to restore beam energy.

Recent Design Changes

- Eliminate Section 2 (β = 0.2 cavities).

  Extend Section 1 to 43 MeV.

  Should reduce cost by eliminating one cavity type.

- Increase β = 0.175 spoke cavity bore radius from 2.0 cm to 2.5 cm.

  Only 5% penalty in cavity efficiency.

- Increase allowed maximum accelerating gradients in spoke cavities by 50% from EoT=5 MV/m to 7.5 MV/m.

  Justified by recent cavity tests.

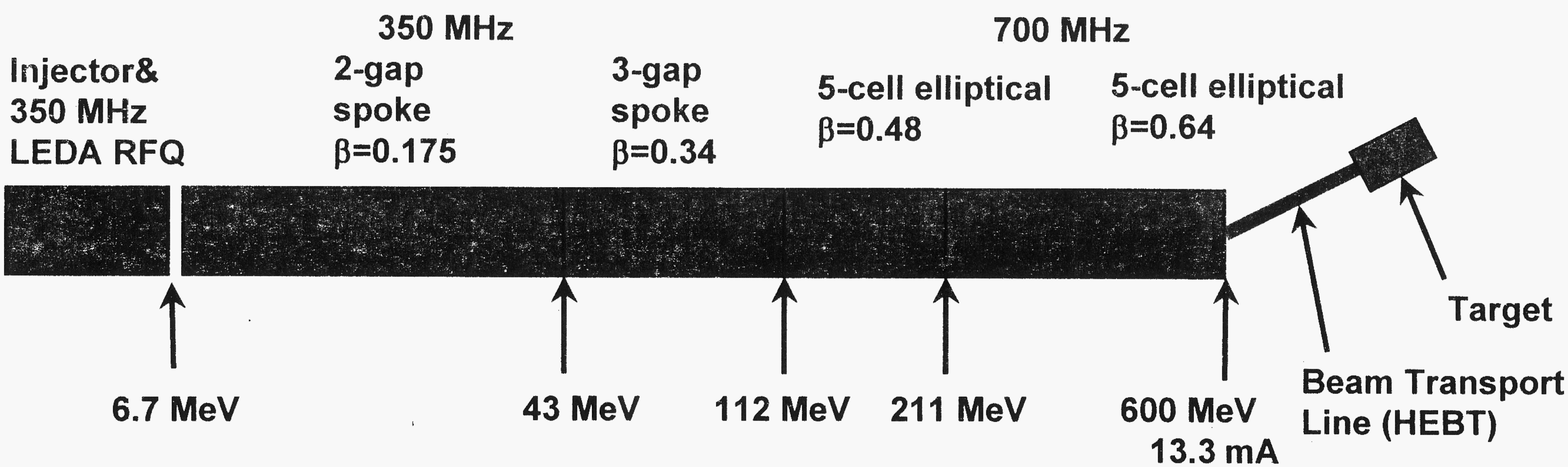
  Reduces overall linac length.

- Increase maximum allowed B_{pk}= 700 Gauss for β=0.48 section.
- Modify design operating parameters to eliminate beam losses at high beam currents (100 mA).

  Preliminary results - modified phase and amplitude ramps

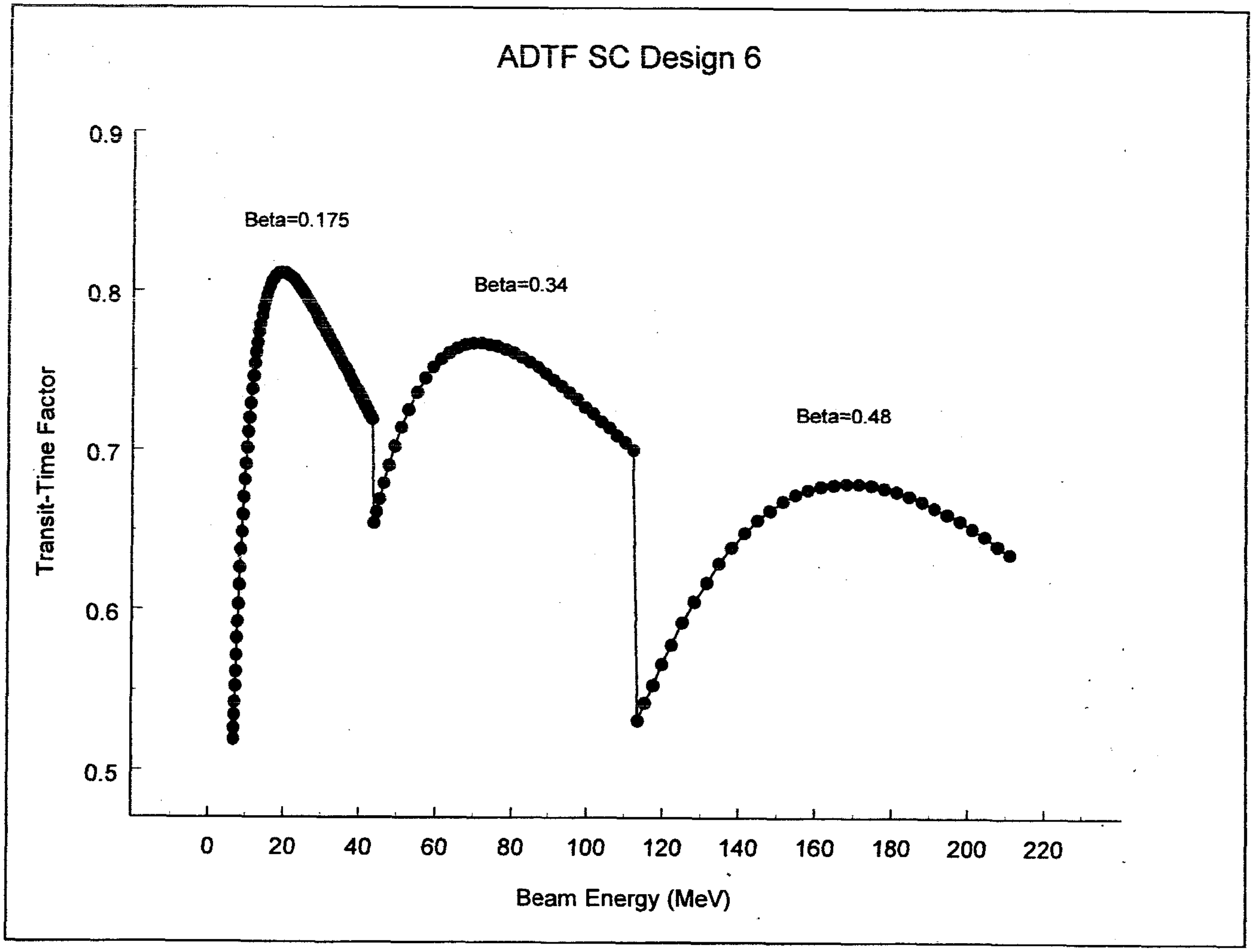
- Simulation results indicate improved beam dynamics performance.

Revised ADTF Superconducting Linac Design

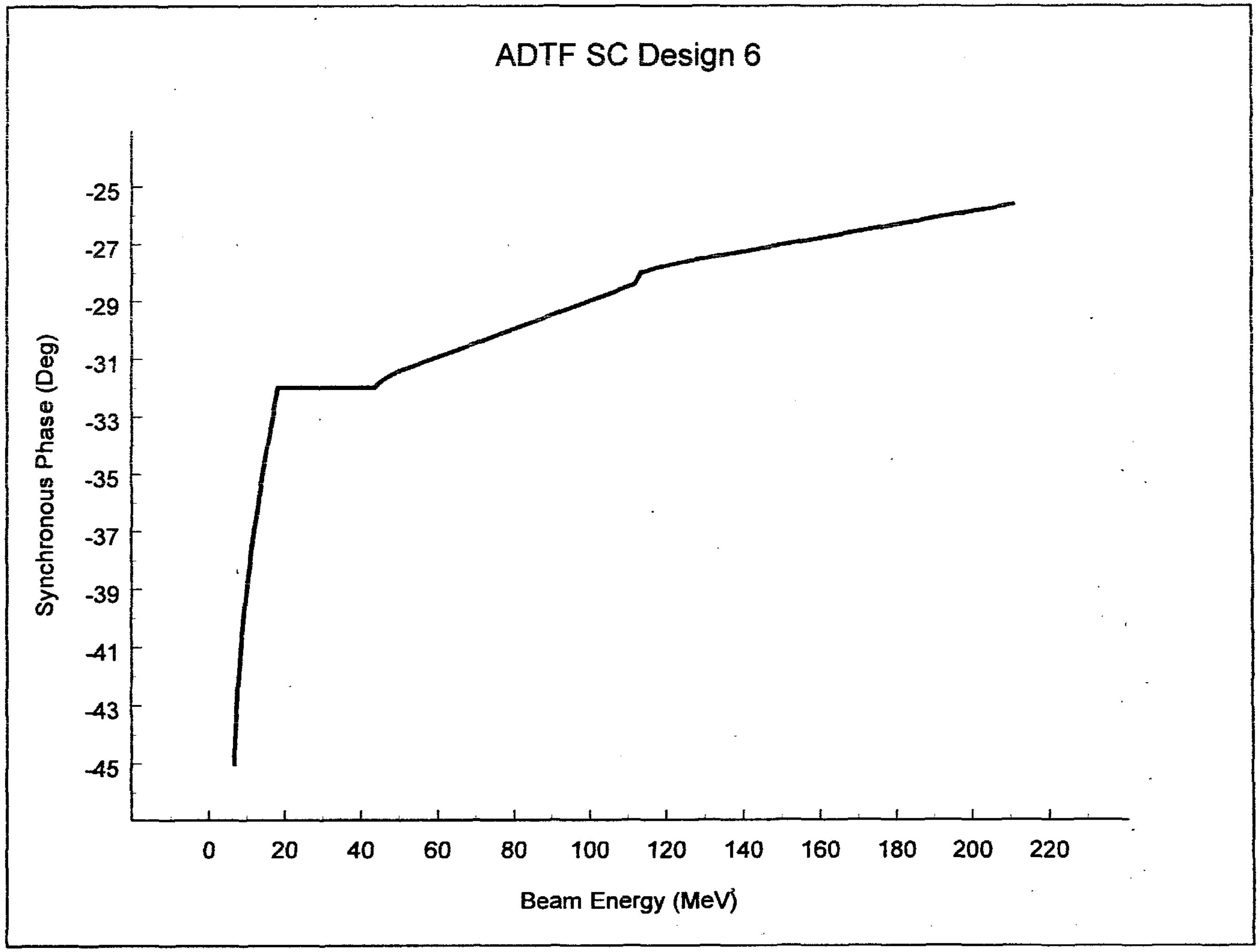


- β=0.2 spoke section eliminated, β=0.175 spoke section extended to 43 MeV.
- β=0.175 cavity bore radius increased from 2.0 cm to 2.5 cm.
- Maximum EoT increased in spoke cavity sections from 5 MV/m to 7.5 MV/m.
- 145 rf generators, 241 superconducting cavities, and 65 cryomodules.
- About 375-m linac length.

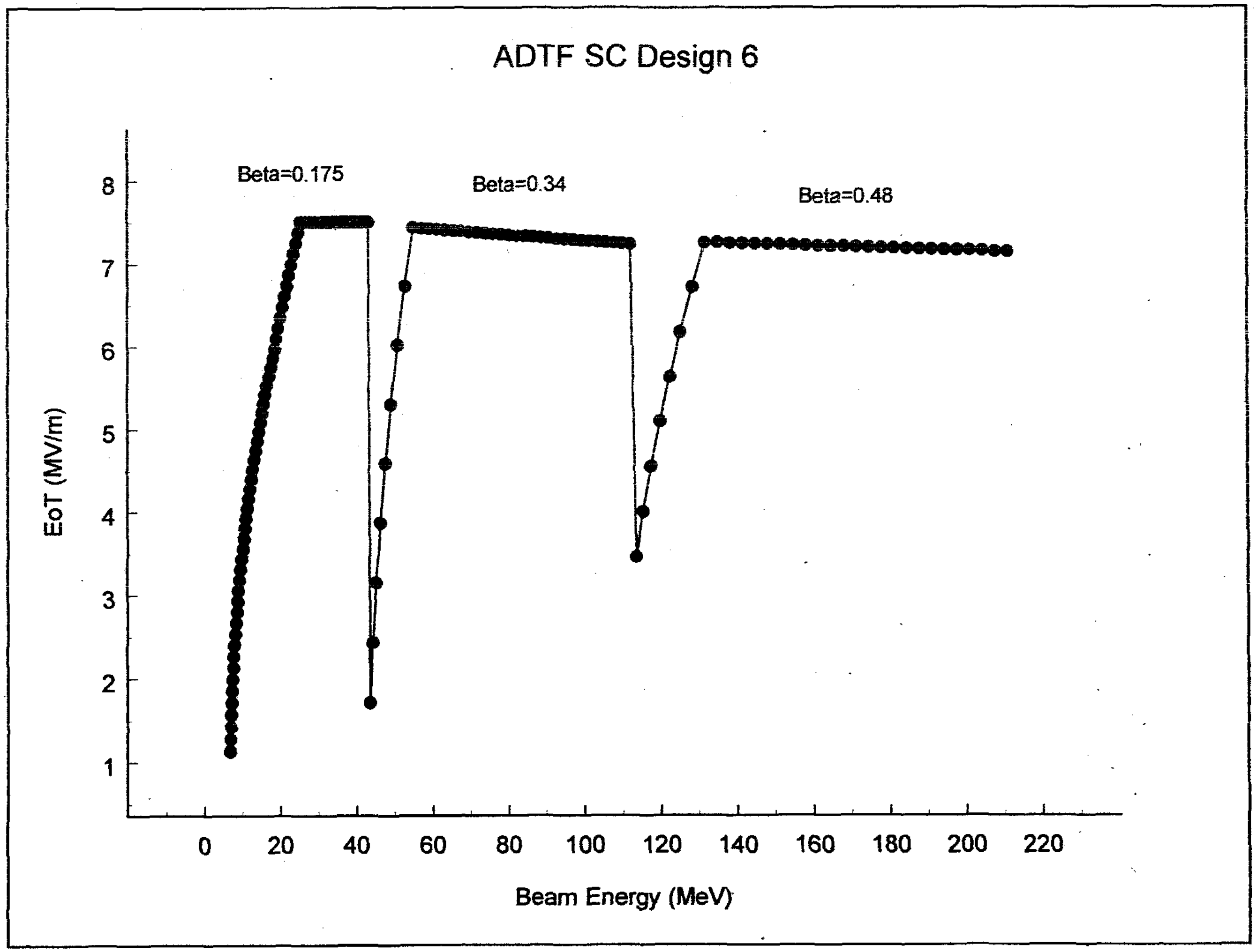
Transit-Time Factor vs Beam Energy



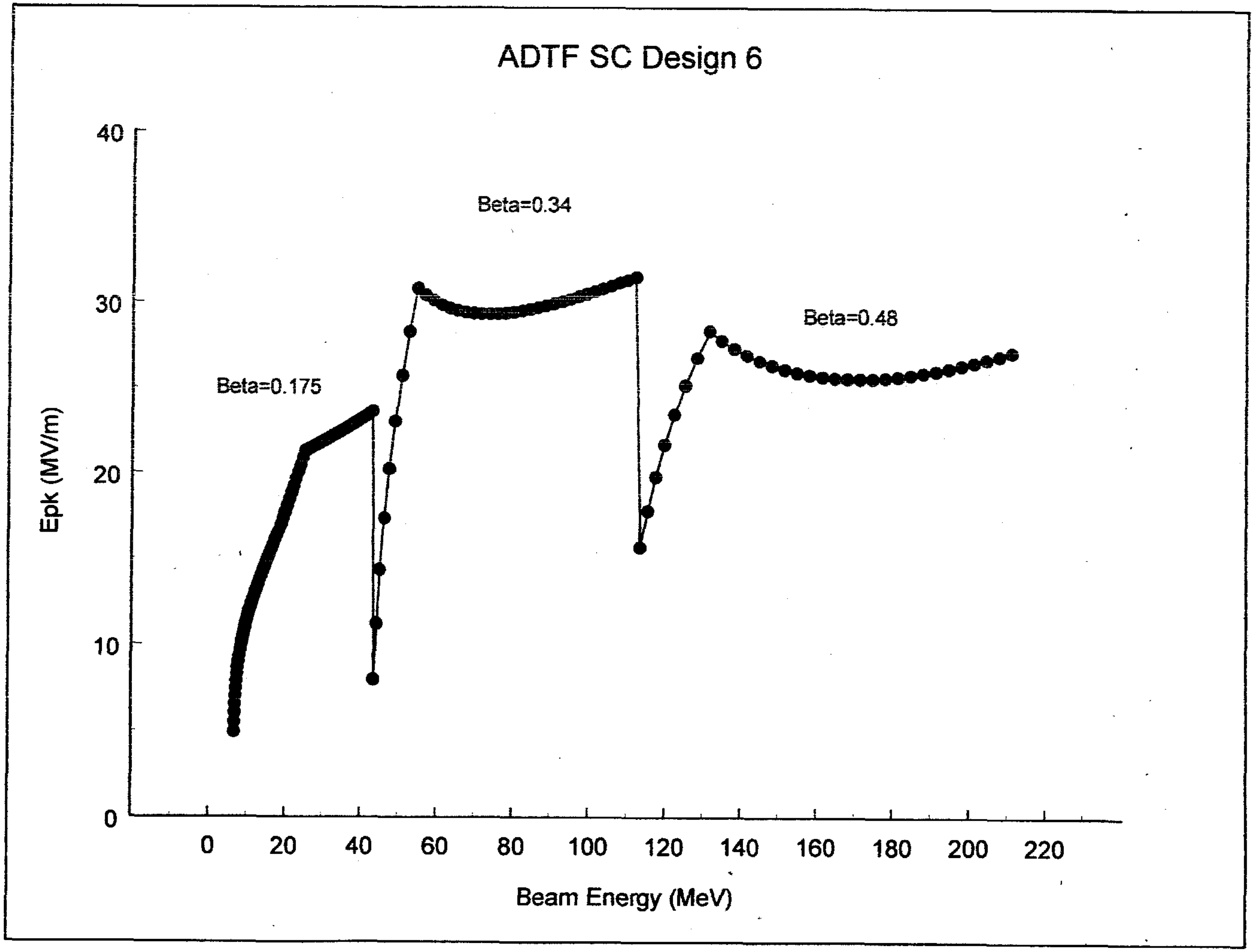
Synchronous Phase vs Beam Energy



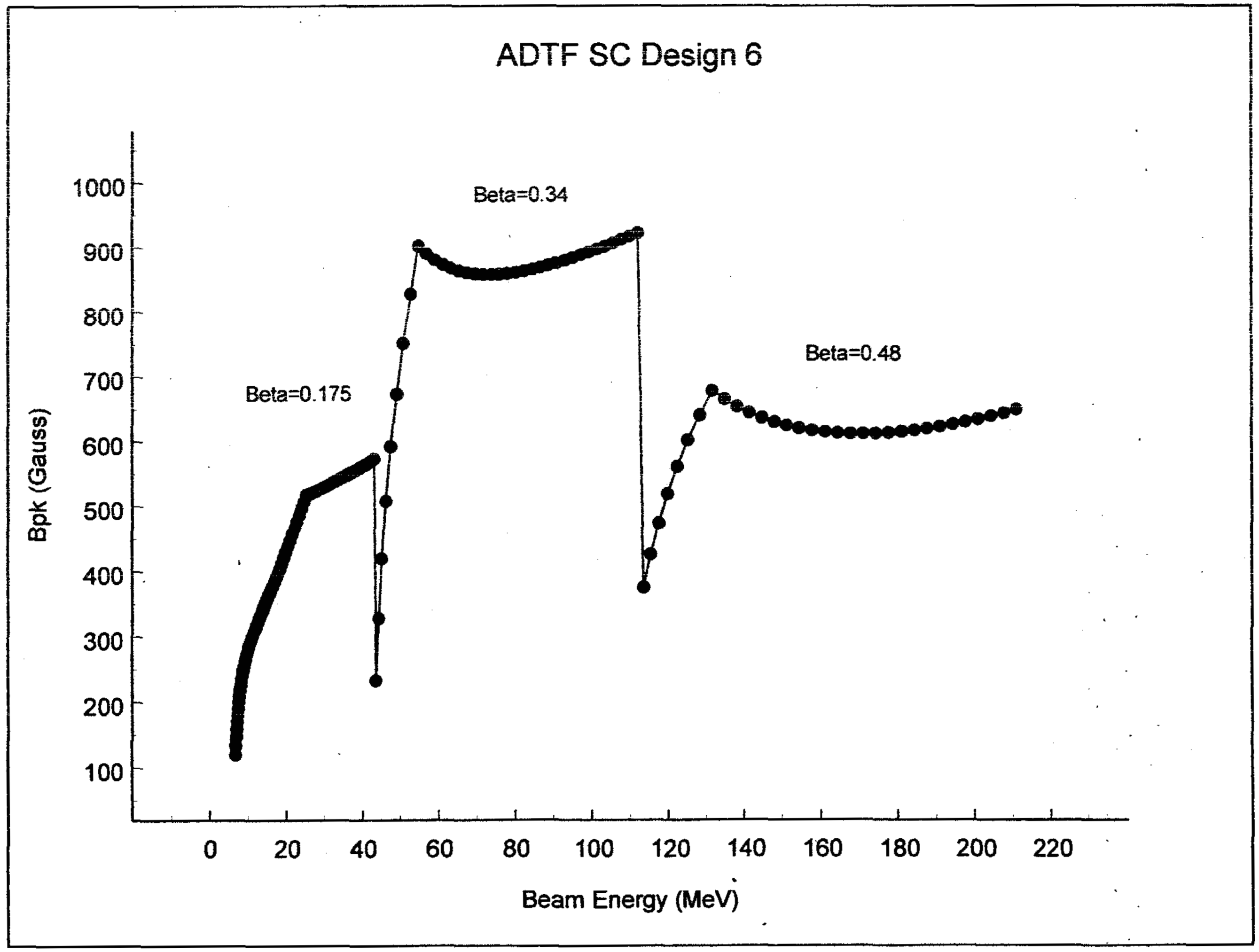
Accelerating Gradient vs Beam Energy



E_{pk} vs Beam Energy



B_{pk} vs Beam Energy



Revised ADTF SC Linac Parameters

	Section 1	Section 2	Section 3	Section 4	Total
Structure Type	2-gap spoke	3-gap spoke	5-cell elliptical	5-cell elliptical	
Frequency (MHz)	350	350	700	700	
Cavity Geometric Beta	0.175	0.34	0.48	0.64	
Cavity Bore Radius (cm)	2.5	4.0	5.0	6.5	
L-cavity (active) (m)	0.100	0.333	0.514	0.685	
L-cavity (physical) (m)	0.200	0.433	0.879	1.159	
L-magnet-to-cavity (m)	0.300	0.300	0.300	N/a	
L-drift1 (m)	0.300	0.300	0.574	0.616	
L-drift2 (m)	1.113	1.113	1.088	0.616	
L-magnet (m)	0.150	0.150	0.250	0.350	
L-warm-to-cold-1 (m)	0.394	0.394	0.394	0.642	
L-warm-to-cold-2 (m)	0.419	0.419	0.394	0.642	
L-warm-space (m)	0.300	0.300	0.300	1.610	
L-cryomodule (m)	4.226	6.624	6.183	4.571	
L-cryoperiod (m)	4.526	6.924	6.483	6.181	
L-focusing period (m)	2.263	3.462	3.338	6.181	
Cav/cryomodule	4	6	4	3	
Cav/section	80	36	32	93	241
No. of cryomodules	20	6	8	31	65
DW/cav (MeV)	0.08 - 0.636	0.482 – 2.118	1.567 – 3.311	4.219	
Synchronous Phase (deg)	-45 to –32	-32 to -28	-28 to –25	-25	
EoT (MV/m)	1.132-7.505	1.708 -7.235	3.453 - 7.145	6.796	
Win,section (MeV)	6.7	43.124	112.010	211.015	
Wout,section (MeV)	43.124	112.010	211.000	600	
DW/section (MeV)	36.424	68.886	98.990	389.000	
Section Length (m)	90.520	41.544	51.864	191.596	375.524
Max Coupler Pwr @ 13.3 mA (kW)	8.459	28.170	44.037	56.11	
Max Coupler Pwr @ 100 mA (kW)	63.60	211.80	331.11	421.90	
No. of Cavities / RF Generator	1	2	2	3	
No. of RF Generators / Section	80	18	16	31	145
Magnet Type	SC Solenoid	SC Solenoid	SC Solenoid	RT Quad Doublet	
Magnet Field / Gradient	1.85 - 3.53 T	3.82 - 5.57 T	4.23 - 5.68 T	4.85 - 6.05 T/m	
Average RE Gradient	0.402	1.658	1.909	2.030	1.495
Total Length Sections 1 - 3 (m)			183.928		